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Monitoring of Land Use/Cover Change Using Remote Sensing and GIS techniques: A case study of Loliondo Game Controlled Area, Tanzania

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Abstract Loliondo Game Controlled Area (LGCA) is unique in East Africa that provides mixed land use activities for the community. The main land uses in LGCA are livestock keeping, wildlife conservation, small scale agriculture, tourism and hunting of wild animals. For decades, Maasai pastoralists coexisted with LGCA but restricted to hunt, set snares and conducting large scale farming. From the year 2000 expansion of agricultural activities have been noted which has escalated the decline of wildlife. I this study the land use/cover change occurred in LGCA for the period of 20 years have been determined and assessed. Supervised classification method was used whereby six classes namely forest, bare land, sand, water, grass land and agriculture were categorized. The results show that from 1996 to 2016 there is a major land cover change on forest, agriculture, bare land, grassland, water bodies and sand by 19.63%, 8.74%, 15.32%, 50.08%, 4.51 %and 1.72%, respectively. Specifically, forest cover is decreasing at 1467.81 ha per year while agriculture is increasing at the rate of 1,467 ha per year. The study concluded that clearing of forest and large scale agriculture has destroyed vegetation cover threatening the existence of wildlife which to a great extent requires immediate measures to counterbalance this effect.

Keywords: *Land use/cover change, Loliondo game controlled area, Maasai pastoralist*

Introduction

Loliondo Game Controlled Area (LGCA) is a unique in East Africa that provides mixed activities for the community. The main land use in LGCA is livestock keeping comprising of pastoralists in about 90 percent of the area, conservation wildlife, small scale agricultures and tourism hunting of wild animals. For decades, Maasai pastoralists have been living in LGCA but restricted to hunt, set snares and conducting large scale farming. However, from 2000 huge expansion of agricultural activities have been noted which has escalated the decline of wildlife. According to the law governing conservation in Tanzania, Loliondo Game Controlled Area falls under the category of Game Controlled Area [1,2]. The Loliondo GCA has an area of about 4,000 km square falls within the Greater Serengeti Ecosystem and traditionally the area is inhabited by Maasai pastoralists who graze their livestock alongside with wildlife. The biodiversity of LGCA is considered to be one of the great wildlife areas in the country. Before 1990, LGCA was designated as high class hunting block under the state owned company namely Tanzania Wildlife Company (TAWICO). LGCA is a state controlled and restricted area for all other activities except licensed hunting and small scale farming. LGCA is a Maasai community concessions and wildlife destination, established in 1959 to provide for wildlife conservation and economic development for Maasai pastoralists [3]. Land management practices of Maasai pastoralist play an important role in maintaining habitat for the world's most spectacular assemblages of terrestrial large mammals [4]. However, for the past 20 years, there have been conservation measures conducted by local government, including introduction of bylaws on land use and community tourism concession agreements. For example, in Terrat village, a unique land easement agreement has been implemented by local government which prohibits agricultural activities inside LGCA [5].

The conservation measures enabled the Maasai communities to formalize their traditional rules and translate them into a modern legal form. Several Acts have been enacted including development of Village Land Forest Reserves under the 2002 Forest Act and Wildlife Management Areas (WMAs) defined in the 2009 Wildlife Conservation Act. These Acts granted communities with user rights over the LGCA. The Act also directs the Minister responsible for Natural Resources and Tourism to protect village land and no village land shall be included in the game controlled areas. Based on this Act, three zones established as categorized in Table 1.

Table 1. The land use zones, policy and tenure

Zone	Policy	Tenure
LGCA	Wildlife tourism, Herding, Small scale farming, and hunting lease.	State controlled and villages
SNP	Wildlife tourism and conservation excluded local land use.	State controlled
NCA	Wildlife tourism and conservation; local land use restricted to herding	State controlled

Study Area

The study area (Figure 1) Loliondo Game Controlled Area was established in 1959 in Ngorongoro district in the Northern part of Tanzania and it is part of Serengeti ecosystem. In the west LGCA is boarded by Serengeti National park, in the south by Ngorongoro Conservation Area and in the north by Maasai Mara in Kenya. Its location extended between latitude 2°and 3° south and between longitude 34°and 36° east. It covers an estimated area of 4,000 square kilometers.

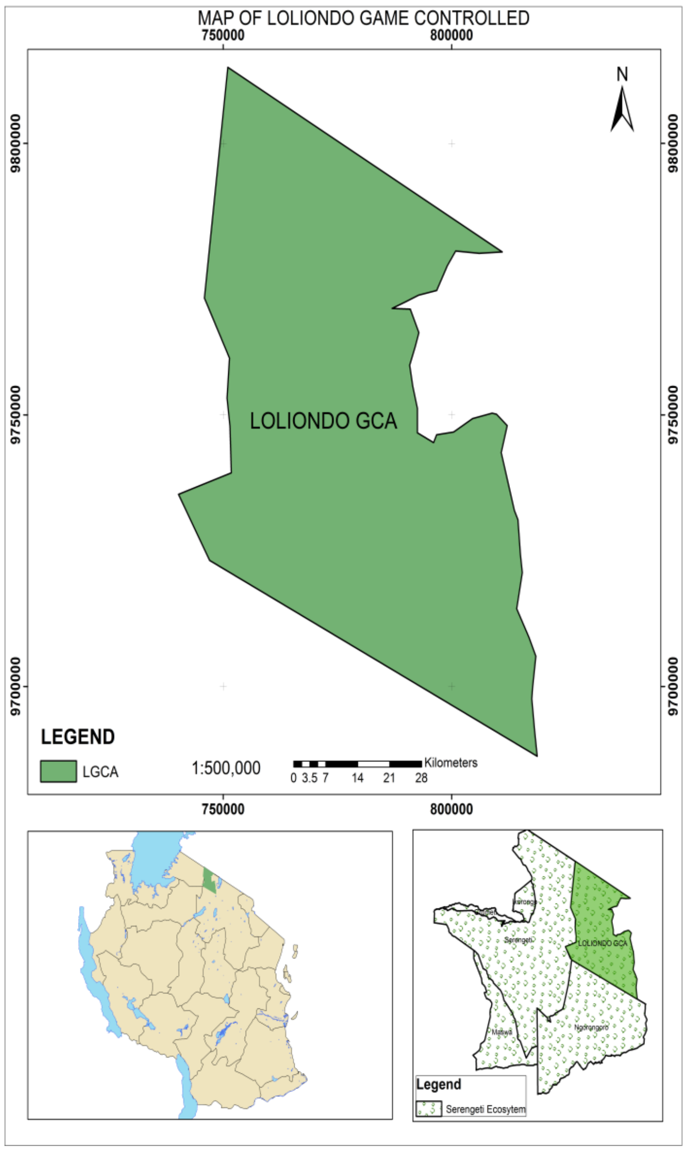

Figure 1. Study Area

Loliondo is among three divisions of Ngorongoro district where other division are Ngorongoro and Sale. The Maasai pastoralists and the Sonjo agro-pastoralists who are the minority are the main ethnic tribe found in Loliondo divisions. The three division's forms the Loliondo GCA. The Maasai pastoralists move freely in LGCA based on an annual cycle of dry and wet seasons [6]. Dry season grazing areas are set aside until the middle of the dry season each year and the village committee decides which and when the community may begin to use the protected areas. The climate in Loliondo is generally warm and dry, with a mean annual temperature of 20.8°C, which is often less than the diurnal variation [7]. The average annual rainfall is between 40cm and 60cm per year [8].

Related Studies

Various studies have been conducted on land use/cover changes over game reserves, conservation areas, National parks and game controlled areas in Tanzania. For decades, Tanzania national parks, game reserve, conservation and Game controlled area are impacted by various activities taking place outside their boundaries. The impact is due to the increase of population, livestock keeping and agriculture activities. It has been reported that, most of protected areas are venerable by the activities surrounding these areas [9].

[10] examined the framing of the resource conflicts in Loliondo Game Controlled Area. The frames analysis revealed that, divergent frames held by the stakeholders led to the protraction of the resource conflicts. The main issues identified were land security, land ownership, unequal tourism benefit sharing and contradicting government policies.

[3] analyzed Landsat images from 1975 and 2000 to determine the trends in vegetation cover. In the study, it was revealed that from 1995 to 2000 there was an increase in forest cover by 48.7%, bush land 42.7% and scrubland by 29.1% and grasslands by -37.0%. In addition, the agreed pastoral land use system preserved the savanna landscape in LGCA whereas conflicting land use policies threatened savanna ecosystem which supports tourism industry in the area.

Material and Methods

Data preparation

The Landsat images of 1996, 2006 and 2016 were downloaded from web site (www.earthexplore.usgs.com) with spatial resolution 30m. The images acquired shows clear vegetation cover and have cloud cover less than 10%. The images were imported into ERDASimagine software and by using combined techniques of remote sensing, GIS and field validation the land use/cover change was determined.

Image processing

Before processing and analysis of the image data, pre-processing routines were applied to the images to enhance the quality of the image by reducing or eliminating radiometric and geometric distortions caused by internal and external conditions.

Layer Stacking

Layer stacking is used to combine separate image bands into a single multispectral image fileand then combining image derivatives with spectral bands for further analysis. Layer stacking was performed to combine separate image bands into a single multispectral image file. For each image, all bands were added expect band 6 which has different pixel size.

Geometric corrections

A geometric correction was performed including correcting for geometric distortions due to sensor-Earth geometry variations and conversion of the data to real world coordinates on the Earth's surface. All sub-scenes were geo-referenced to universal Transverse Mercator (UTM) projection. During projection of sub-scenes three parameters were defined in zone 36S, ellipsoid (WGS84) and datum (WGS1984) to account for geometric distortions.

Mosaicking and image clipping

After all sub scenes were geo-referenced using ERDAS imagine software, mosaicking was performed to obtain a complete and continuous view of the study area. Image clipping was performed to remove unwanted parts of an image or object from the entire image.

Image enhancement

Image enhancement was achieved to improve the contrast between features by modifying the brightness values (BV) for easy image interpretation. The image enhancement applied includes liner contrast stretching. Since linear contrast stretch alters the statistical data, principal component analysis was also used to improve the visual appearance of the features/objects.

Image classification

Based on the priori knowledge of the study area for over 20 years, reconnaissance survey and additional information gathered from previous research, a classification scheme developed by [11] was adopted with some modifications. Table 2 shows 6 land use classes adopted in this study.

Table 2. Land covers types

Code	**Land use class**
1	Forest
2	Agriculture
3	Bare land
4	Grassland
5	Water bodies
6	Sand

To determine the land use/cover classification, supervised classification method was used in ERDAS Imagine software which is mainly based on the prior specification of training areas. The supervised classification is based on the probability that a pixel belongs to a pre-determined class. The concept assumed that the probability is equal or the same for all classes. The advantage of this method is based on the fact that the classes tend to conform to the classification hierarchy because the classes are user defined. The limitation of supervised classification is that the selected classes tend not to match with spectral classes and in some cases the homogeneity of information classes tends to vary.

Maximum likelihood was applied as image classifier which is based on statistical parameter of specified classes from training samples. This method calculates likelihood with which every pixel belongs to in the image belongs to these classes. During classification process, every pixel was assigned into a class with highest likelihood. The training areas were entered into Arc Map software to create shape file that was used as an input into ERDAS imagine software for further classification. The advantage of maximum likelihood classifier is vested on the fact that it considers the variability within a cluster, shape, size and orientation of clusters.

After supervised classification, a post classification approach was performed followed by pixel based comparison so as to provide changes of the images on pixel that interprets changes more easily. The classified images for the period of 1996, 2006 and 2016 were compared using cross tabulation to determine the qualitative and quantitative changes for the period of 20 years. A change detection matrix was computed with the assistance of ArcMap software which show land use / cover changes in each class. A Normalized Difference Vegetation Index (NDVI) developed by [12] was used to separate vegetation from other features in the images. The NDVI was determined using the expression given in Equation (1)

$$\text{NVDI} = \frac{NIR-R}{NIR+R} \quad (1)$$

Where NIR = Near Infra Red (band 4 for Landsat TM), R = Red (band 3 of Landsat TM images)

Ground truthing

Ground truth refers to the data collected from site, which allow image data to be related to real features and material on the ground. Sample coordinates from study area were acquired using handheld Global Position System (GPS) (Garmin –Etrex 20).

Accuracy assessment

Accuracy assessment is an essential part after image classification process as it helps to understand and determine the relevancy of the results. The accuracy assessment was done by comparing objects in the image and the objects obtained in the field. After error matrix was computed and the overall, kappa, users and producer accuracies were determined. In this study, the overall accuracy of classification was derived using equation 2:

$$\text{Overall Accuracy} = \frac{\text{No.of pixels correctly calssified}}{\text{Total number of pixels}} \quad (2)$$

Kappa analysis being a standard component for accuracy assessment [13] is used to measure the agreement or accuracy between the remote sensing derived classification map and the reference data as indicated by the major diagonals and the chance agreement, which is indicated by the row and column totals [14]. Kappa coefficient would be defined from 0 to 1. If kappa coefficient were equals to 0 there was no agreement between classified image and referenced image, conversely, if kappa coefficient was equal to 1 it shows that there was a strong agreement between classified image and ground truth data.

The Kappa factor was computed using equation 3 below:

$$\text{Kappa} = \frac{p_o - p_e}{1 - p_e} \tag{3}$$

Where: *Po = is the proportion of correctly classified cases*

Pe = is the proportion of correctly classified cases expected by chance

Producer accuracy is a measure how well a certain area can be classified [14], while Users Accuracy is the total number of correct pixels in a category divided by the total number of pixels that were classified in that category (row total), the result is a measure of commission error.

Results and Discussion

Classification Accuracy Assessment

The accuracy assessment of image classification was determined using equations (2) and (3), and the results obtained are summarized in Table 3, Table 4, and Table 5. The results obtained show the overall accuracy, Kappa coefficient/statistics, producers and user accuracy for classified Land Sat images of 1996, 2006 and 2016.

Table 3. Accuracy of Land sat imagery 1996

Class Name	Reference Total	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Sand	23	27	21	91.30%	77.78%
Water bodies	8	8	6	75.00%	75.00%
Bare land	16	11	11	68.75%	100.00%
Agriculture	12	12	12	1000.00%	100.00%
Grassland	38	53	38	100.00%	71.24%
Forest	6	8	6	100.00%	75.77%

Overall Classification Accuracy = 85.55%

Overall Kappa Statistics = 0.8194

Table 4. Accuracy of Landsat imagery 2006

Class Name	Reference Total	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Sand	22	23	22	100.00%	95.65%
Water bodies	8	8	8	100.00%	100.00%
Bare land	1	4	1	100.00%	25.00%
Agriculture	23	16	16	69.57%	100.00%
Grassland	16	37	16	100.00%	43.24%
Forest	30	31	30	100.00%	96.77%

Overall Classification Accuracy = 84.97%

Overall Kappa Statistics = 0.8168

Table 5. Accuracy of Landsat imagery2016

Class Name	Reference Total	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Sand	22	23	22	100.00%	95.65%
Water bodies	19	18	18	90.00%	100.00%
Bare land	19	17	16	84.21%	94.12%
Agriculture	14	14	14	100.00%	100.00%
Grassland	12	19	12	100.00%	63.16%
Forest	32	32	31	96.88%	96.88%

Overall Classification Accuracy = 87.86%

Overall Kappa Statistics = 0.8526

Land covers change

The classified Landsat images for 1996, 2006, and 2016 were used to determine the extent of changes occurred in LGCA. The area in hectares of each land use class was calculated from the three classified images using ArcGIS 10.0 software and subsequently the results were compared. The comparison of the Land use/cover statistics was used to define the percentage of change, trend and rate of change from 1996 to 2016. Table 4 shows the area in hectares and the percentage change for each year from 1996 to 2016. The percentage of change was calculated by dividing observed change and sum of changes multiplied by 100 as shown in equation 4 developed by [15].

$$\text{Trend change} = \frac{observed\ change}{Sum\ of\ change} * 100 \tag{4}$$

The rate of land cover change of LGCA from 1996-2006 and 2006-2016 were obtained from processed Land sat image using six classes namely water bodies, forest, grassland, bare land and sand. Equation 5 below was used to calculate the rate of land cover change.

$$\text{Rate} = \frac{Observed\ change}{Number\ of\ years} \tag{5}$$

As shown in the Table 4, Table 5, and Table 6 above, the mean overall classification accuracy was 86.3% while the mean kappa statistics was 0.8296. The reason for lower overall accuracy obtained on 2006 image is due to the line strips which made the process of identifying different land use/land cover more difficult. Figure 2, Figure 3, Figure 4 and Figure 5 show the land cover change map from 1996 to 2016.

Land use/cover change

Table 7 below shows the distribution of land cover types of LGCA. The results indicate that the dominant land cover type is grassland which is about 45.38%, 46.44%, 50.08% for 1996, 2006 and 2016 respectively. Taking year 1996 as reference, the result shows that forest cover was found to be decreasing from 278053 ha in 1995 to 174210 ha in 2016. Percentagewise, the forest decreased from 31.34% in 1996 to 9.63% in 2016. The decrease of forest cover has been contributed by population increase and clearing of forest for agricultural activities.

Water bodies were also found to be decreasing from 6430.67 and 5219.97 between 1996 and 2006. The decrease of water bodies have been contributed by anthropogenic activities as well as climate change which was also noted by [5]. However increase of water bodies from 2006 – 2016 was due to heavy rainfall during that period.

Agricultural activities increased from 21082.33 ha to 77560.5 ha between 1996 and 2016 which is from 2.38% to 10.40% respectively. The bare land was found to be slightly stable as it was estimated to be 140425, 141163 and 141163 for year 1996, 2006 and 2016, respectively.

The grassland was found to be increasing from 402684 ha in 1996, to 444376 ha in 2016. Table 6 show areas and percentages of six land cover classes while Table 7 show the Area change in (Ha) and rate of land cover change in (Ha/years). Table 8, Table 9, Table 10 and Table 111 show the matrices of land cover change from 1996-2006, 2006 – 2016 and from 1996 – 2016.

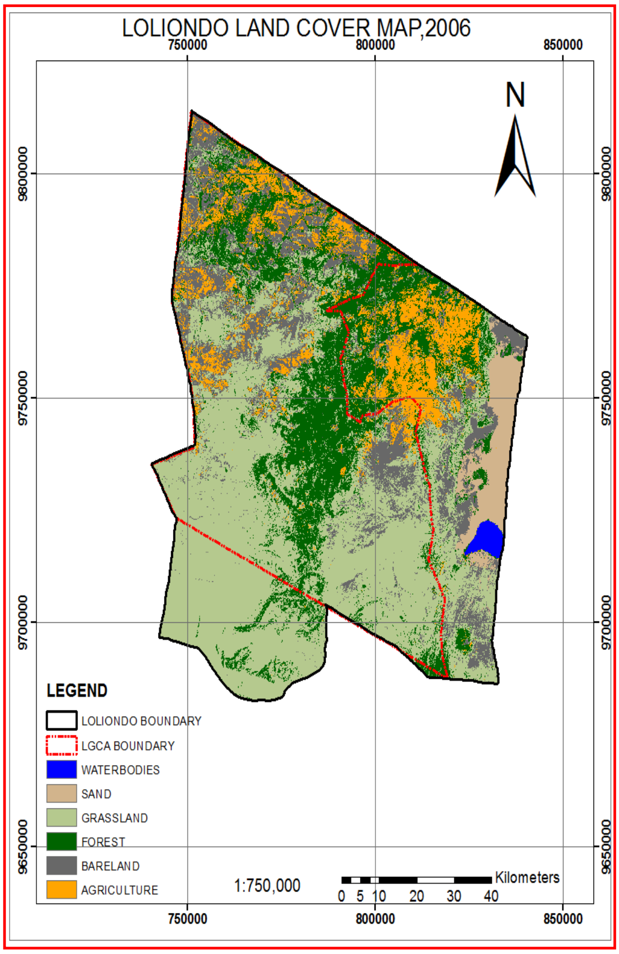

Figure 2. Classified Landsat image 4-5 TM, 1996

Rate of land covers change

The study shows that forest decrease at rate (Ha/years) of -77064 to -26779 from 1996 to 2006, respectively. Agricultural activities increased from 1996-2006 at the rate of 71156.27 ha/year. The rate of change for bare land was 73.8 Ha/year between 1996 and 2006 while between 2006 to 2016 changed at -523.4 ha/year. Water bodies changed at the rate of -1210.7 ha/year between 1996 and 2006 was -2037.35 ha/year. Figure 6, Figure 7, Figure 8 show the land cover change from 1996 to 2016.

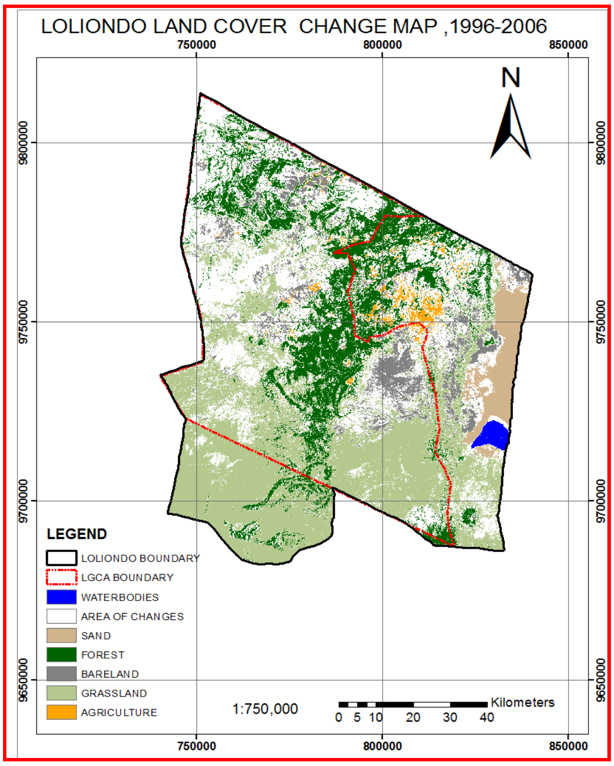

Figure 3. Loliondo land cover map 1996-2006

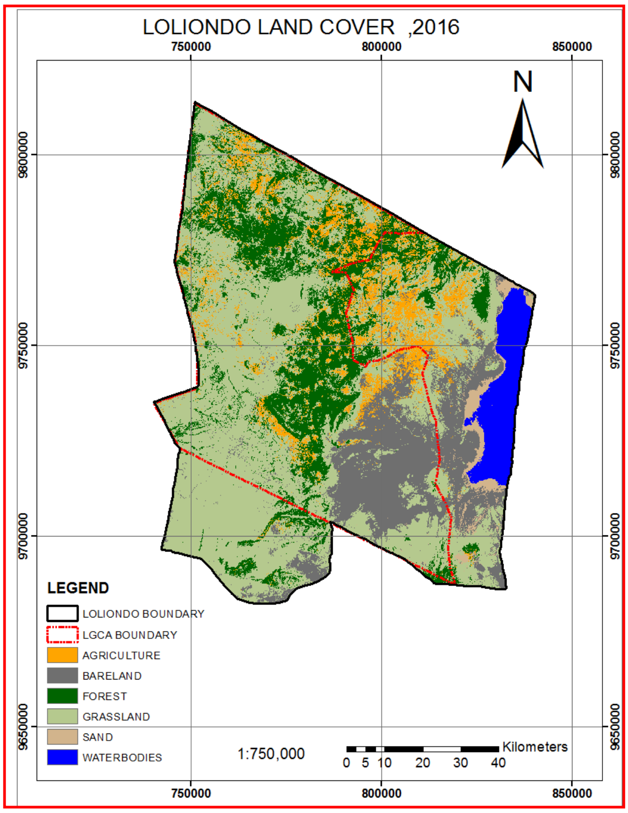

Figure 4. Classified landsat image 2016

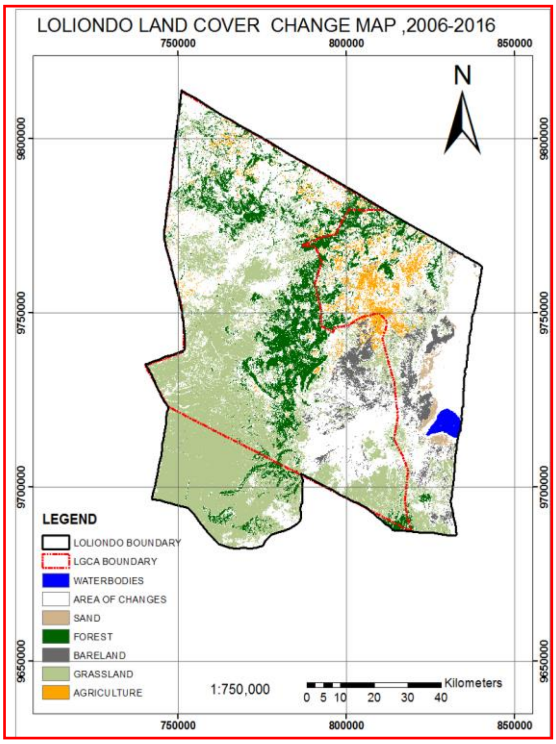

Figure 5. Loliondo land cover map 2006-2016

Table 6. Areas and percentage of six land cover classes

Land cover Class	1996 Area	1996 %	2006 Area	2006 %	2016 Area	2016 %
Sand	38657.9	4.4	35615.9	4.0	15242.4	1.72
Water bodies	6430.7	0.72	5220	0.59	40014.8	4.51
Bare land	140425	15.82	14163	15.91	135929	15.3
Agriculture	21082.3	2.38	92238	10.40	77560.5	8.74
Grassland	402684	45.4	412106	46.4	444376	50.1
Forest	278053	31.34	200989	22.65	174210	19.63
Total	**887332.9**	**100**	**887332.5**	**99.9**	**887332.9**	**100**

Table 7. Area change in (Ha) and rate of land cover change in (Ha/years)

Land Cover Type	Net Area change (Ha)	Percentage change	Net Area Change (Ha)	Percentage change	Rate of land cover change (Ha/Year)	Percentag e change
Type	1996 – 2006	%	2006 – 2016	%	1996 -2016	%
Sand	-3042	-0.4	-20373.5	-2.3	-3042.4	-2.7
Water bodies	-1210.7	-0.1	-20373.5	3.9	1210.7	3.8
Bare land	738	0.1	-5234	-0.1	73.8	-0.5
Agriculture	71156.27	8	-14678.1	-1.7	71156.27	6.4
Grassland	9422	1	32270	3.7	942.2	4.7
Forest	-770664	-8.7	-26779	-3	-77066.4	11.7
Total	**887332.9**		**100**		**887332.5**	

Figure 6. A graph represent land covers change between 1996-2016

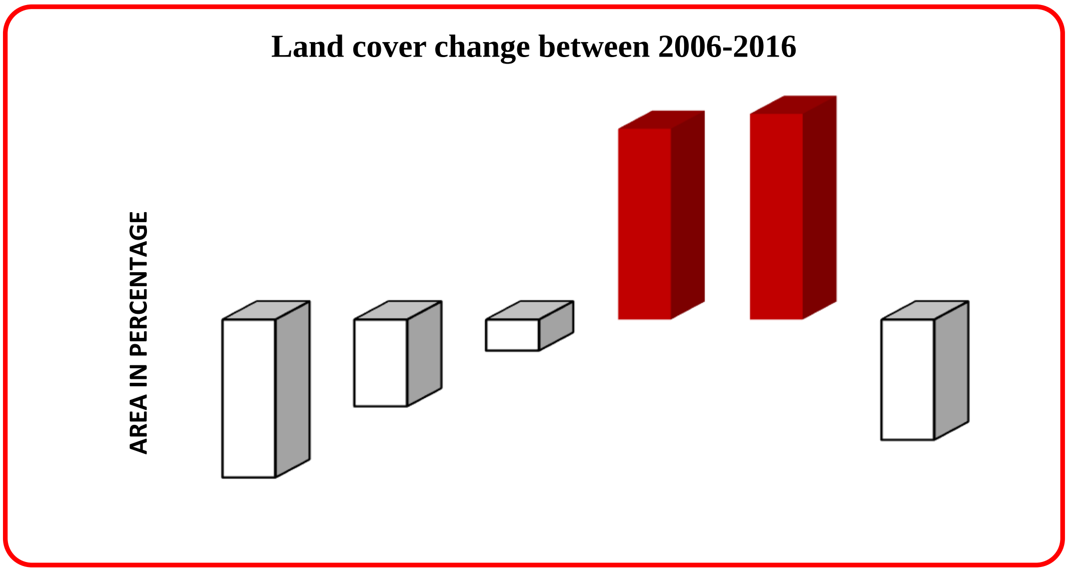

Figure 7. A graph represent land covers change between 2006-2016

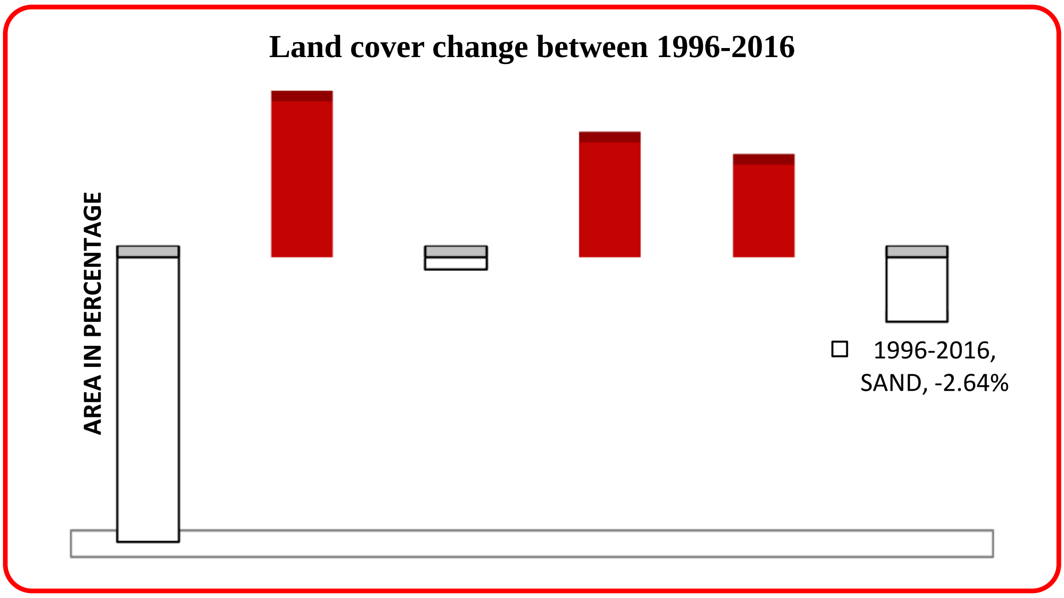

Figure 8. A graph represent land covers change between 1996-2016

Table 8. Matrix of land cover change from 1996-2006 in (ha)

1996 - 2006	Land cover class in 2006 (Ha)						
	Class name	Water bodies	Sand	Forest	Bare land	Grassland	Agriculture	Total
Land cover class 1996 (Ha)	Water bodies	5214.3	862.5	263.1	1.1	16.3	72.8	6430.8
	Sand	2.79	32088	2776	3487	226	73	38658
	Forest	0.99018	67.15	163471	29357.3	43954.7	41148.8	278053
	Bare land	0.09	835	2875	54481	65514	16704	140425
	Grassland	0.18	1752.4	27241	52042	299879	21717	402684
	Agriculture	0	0.63	4343.7	1786.8	2421.6	12521.4	21082.4
Total Area		**5219.5**	**35615.9**	**200989**	**141163**	**412105.9**	**92239.3**	**887332.6**

Table 9. Matrix of land cover change from 1996-2006 in (%)

1996 - 2006	Land cover class in 2006 (%)							
	Class name	Water bodies	Sand	Forest	Bare land	Grassland	Agriculture	Total
Land cover class 1996 (%)	Water bodies	81.09	13.41	4.09	0.02	0.25	1.13	99.99
	Sand	0	83.01	7.18	9.02	0.59	0.19	99.99
	Forest	0	0.02	58.81	10.56	15.81	14.8	100
	Bare land	0	0.59	2.05	38.81	46.65	11.9	100
	Grassland	0	0.44	6.76	12.92	74.48	5.4	100
	Agriculture	0	0	20.6	8.48	11.48	59.43	99.9
Total Area		**0**	**0**	**20.6**	**8.48**	**11.48**	**59.4**	**99.9**

Table 10. Matrix of land cover change from 2006-2016 (Ha)

1996 - 2006	Land cover class in 2006-2016 (Ha)							
	Class name	Water bodies	Sand	Forest	Bare land	Grassland	Agriculture	Total
Land cover class 2006 (Ha)	Water bodies	5214	5.67	0	0	0	0	5219.97
	Sand	31254	5894.59	2.88	32.3	28.1	3.78	35615.9
	Forest	1791.9	1549.3	113360.7	3020.4	55905	24761.8	200989
	Bare land	1596.9	4815.9	13480.1	73598.4	36838.3	10833.3	141163
	Grassland	65.6	2887.5	34056.3	94782.6	268447.3	11866.7	412106
	Agriculture	88.85	97.9	13294.9	2247.8	30078.6	46430.7	92238.7
Total Area		**40014.8**	**15242.4**	**174210**	**135929**	**444376**	**77560.5**	**887322.6**

Analysis of the results

Agriculture

From 1996 to 2006 the agricultural area increased from 21082.33ha to 92238.6 ha. However, from 2006 to 2016 there was decrease from 92238.6 ha to 77560.5 ha. From 1996 to 2006 there was increase in anthropogenic activities where forest and grasslands was converted into agricultural lands and this has raised concerns from conservationists and the government on the disruption of the buffer zone and migratory routes from Maasai Mara National Park in Kenya to Serengeti and Ngorongoro National parks in Tanzania.

Table 11. Matrix of land cover change from 2006-2016 in (%)

2006-2016	Land cover class in 2016 (%)							
	Class name	Water bodies	Sand	Forest	Bare land	Grassland	Agriculture	Total
Land cover class 2006 (Ha) l	Water bodies	99.89	0.12	0	0	0	0	100
	Sand	87.75	16.55	0	0.09	0.08	0.01	99.98
	Forest	0.89	0.77	56.4	1.5	27.81	12.32	99.99
	Bare land	1.1	3.4	9.55	52.13	26.1	7.67	100
	Grassland	0.02	0.7	8.26	23	2.83	2.88	100
	Agriculture	0.1	0.12	14.41	2.44	32.61	50.34	100

Forest

From 1996 to 2016 the area under forest decreased from 278053 ha in 1996 to 174210 ha in 2016. The decreasing is associated with human activities including clearance of forest for agricultural activities. The trend of forest cover decrease was also reported by [3] where investigated the vegetation changes in Ngorongoro Conservation Area.

Sand

From 1996 to 2006 the area under sand decreased from 38657.9 ha in 1996 to 35615.9 ha in 2006 and 15242.4 ha in 2016. The sand area decreased from 1996 to 2016 due rainfall in the LGCA which tends to fill water in Lake Natron from January to April hence reducing sand areas surrounding the lake.

Bare land

From 1996 to 2006 the bare land increased from 140425 ha in 1996 to 141163 ha in 2006. Also during this period there was an increase in anthropogenic activities in LCGA whereby forest and grasslands were converted into agricultural lands which increased the bare land. However, from 2006 to 2016 there was decrease in area under bare land to due conversation awareness campaign launched in 2000 by the government.

Grassland

From 1996 to 2006 the grassland increased from 402684 ha in 1996 to 444376 ha in 2016. The increasing pattern is due to clearing of forest that enhances the penetration of sunlight to grasses that were under forest shades.

Conclusion

This study indicated that the land cover in LCGA is changing drastically. The magnitude of land use / cover change on forest, agriculture, bare land, grassland, water bodies and sand is 19.63%, 8.74%, 15.32%, 50.08%, 4.51 %and 1.72%, respectively. Specifically, the forest cover was found to be decreasing at 1467.81 ha per year while agriculture has been increasing at the rate of 1467 ha per year. The change is threatening the wellbeing of Maasai pastoralists and wild animals. In addition, the increase of agriculture activities in LGCA is affecting the sustainability of LGCA and its ecosystem.

Recommendations

Based on the result, large scale agriculture and excessive livestock activities should be restricted in LGCA. Programs of forest restoration, conservation measure should be initiated and implemented in the LGCA.

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